Comments on Water Heating Distribution Systems

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I made many comments during the workshop held on April 23, 2002. The purpose of this document is to highlight the most important ones.

1. My major concern is with the relative values in Table 2.2 Proposed ACM DSMs. My concern is based on the following:

- I found what appears to be an error in the relationships between the five recirculation systems. This assessment is based on my review of the information provided by ACT Metlund Systems to the Davis Energy Group. There appear to be discrepancies between the data supplied to DEG and the numbers shown in Table 20-Summary of Recirculation Distribution Loss (DL)) Results. The DL Therms do not seem to include all of the energy costs, only the extra energy due to the use of the recirculation system. The ratios in the table also do not seem to account for the energy costs to run the pumps. It would seem to me that the ratios should include all of the costs. I have not seen the calculations for the temperature and timer/temperature systems and so cannot comment on them at this time. It would be useful to look at all of them together.

- I still have questions about the accuracy of the mathematics in the model. I do not see that it accurately accounts for the energy use in the cases that I am most familiar with. Here are some of my questions:

    - How does it account for effective pipe length (elbows, tees, heat traps, other restrictions)
    - How does it account for the mass of pipe and the materials surrounding the pipe both during the warm up phase and during the use phase?
    - At start-up in the morning (and probably at the beginning of the evening use period) the model probably assumes a 65 or 70F starting temperature in the lines. Based on the decay curves shown in the Parallel Piping Study, it would appear that in almost all of the draws when the pipes are uninsulated, that the entire volume of water in the pipe must be displaced before hot water will arrive at the fixture. (It takes less than 6 minutes to get below 105F) What temperatures does the model use when calculating the wasted energy for the intermediate cycles? Does it assume that the entire volume of water must be displaced?
    - Does the model use the actual flow of 135F high temperature hot water or does it use the full volume of 105F average temperature hot water for the average temperature draws? I think that the energy associated with wasted water is more accurately modeled using the actual flows of 135F water. This is because this is

the amount of water that was actually heated and because the pipe losses are proportional to the actual temperature and flow rate of the water in the pipe.

  - The model appears to treat the energy lost based on the decay rates in different diameters of pipe the opposite of what occurs during the delivery of hot water to the fixtures. The decay rates for different diameter pipes are presented in one of the references used by DEG. In these charts, the decay rates are lower for larger diameter pipes than for smaller diameter pipes. Wouldn't this mean that the time to heat up larger diameter pipes is greater than for smaller diameter pipes? And similarly, isn't the energy loss greater? Does the model properly account for this?
  - Does the model account for the line losses during the use of the hot water? A very real issue is that hot water temperatures are being lowered to minimize scalding (temperature limiting fixtures are also being required). Uninsulated lines lose a significant amount of heat and it is easily possible to find situations where the hot water will be barely warm enough to use, even at 105F. This means that virtually no mixing takes place. It also means that the temperatures in the pipes will spend more time in the ideal range for supporting bacteria growth.
  - What will happen to the validity of the results if Federal or State regulations take effect that limit the temperature of the water heater to 120F? How will that impact the ability of a given distribution to provide water hot enough to shower with at fixtures far from the water heater?
  - How does the model address fixtures with mixing valves? These are very common in new construction. It appears that the least expensive ones (those the builders are most likely to use) have a fixed mixing percentage (say 60/40). This means that the flow rate of hot water is even lower than what it would be based on ratio needed to achieve a desired mixed temperature.

- The paper states that comparisons were not done for standard plumbing systems, parallel piping systems and recirculating systems in the same houses. I believe that this is an important omission. It is important for a few reasons: 1)Table 2.2 is intended to show the relative comparisons between options and unless the options all have the same baseline, the comparisons are not very useful; 2)With cities throughout the state beginning to mandate recirculating systems in all new construction in order to save water, the Commission's standards should provide useful information to assist this resource goal; 3)We want people to choose to install the most efficient system(s), and one of the best ways to do this is to have the standards accurately reflect the relative values between the options.

2. I would like to propose a way of characterizing the different systems discussed in the paper. It seems to me that reducing the amount of water lost waiting for hot water to get to the fixtures is one of the best ways to improve the efficiency of the hot water delivery system. The other is to insulate the lines so that the water stays hot longer, thus improving the performance of the distribution system for draws relatively close together in time on the same line.

I would suggest that we should base our standard for hot water distribution systems on providing hot water of a defined temperature (say 135F) to all fixtures in less than a certain number of time (say 5 seconds), with a water loss of less than certain volume (say 8 ounces). This means that water loss would be minimized, while at the same time providing the greatest convenience and level of service. (I am not saying that the values shown above are the correct ones. They are just examples for our discussion.) Mixing, both for preference and to prevent scalding should take place at the fixtures, not at the water heater.

First I would like to provide some definitions for the three types of delivery systems discussed in the paper.

- Standard Plumbing: This type consists of a main trunk (typically ¾ or 1″ diameter) which delivers water to branches (½″ diameter) that have a relatively long way (generally longer than 10 feet) to deliver water to the fixtures. The distance from the water heater to the furthest fixture is often 70 feet. There are a relatively large number of elbows and tees which increases the losses due to effective pipe length.

- Parallel Piping: This type consists of separate branches (fixed at ½″ diameter in this study) running from a manifold very close to the water heater, directly to most fixtures. The exceptions are bathrooms that contain two lavatory fixtures and kitchens that contain a sink and a dishwasher. As shown on drawings contained in the Parallel Piping Study, these lines do not necessarily run straight to the fixtures, rather they follow the building wall layout for some significant portion of their length. Lengths vary from very short, less than 10 feet to very long, more than 70 feet. The fact that there are relatively few elbows, tees or other restrictions minimizes the losses due to effective pipe length. (I have been informed by at least one plumber that he rarely sees a single manifold system. He says it is much more common to see multiple "mini-manifolds" located at appropriate points on a main trunk line of relatively large diameter (3/4, 1 or even 1 1/4″). The manifolds are used because they make it easy to use PEX, which is much easier than copper to install, to distribute water to each fixture. However, since they are installed on a typical trunk line, many of the claimed benefits or using parallel piping systems are lost. Wirsbro is one type of manifold seen in the field in this configuration.)

- Recirculation Systems: This type consists of a trunk (typically ¾ to 1″ diameter) that makes a loop out past the furthest fixture back to the water heater. There are different methods of providing hot water to the loop: continuous, timer, temperature, time/temperature and demand control. The length of the branch between the loop and the fixture is specified at less than 8 feet of ½″ diameter pipe. There are a moderately large number of elbows and tees which increases the losses due to effective pipe length.

The table below shows the relative area for different pipe sizes based on nominal diameters of the pipes. Using actual internal pipe diameters could refine this analysis. It could also be refined by accounting for the additional losses due to effective pipe length.

Diameter	3/8	1/2	3/4	1
Radius	0.1875	0.25	0.375	0.5
R Squared	0.035	0.063	0.141	0.250
Ratio to 3/8	1.0	1.8	4.0	7.1
Ratio to 1/2		1.0	2.3	4.0
Ratio to 3/4			1.0	1.8

What I want to explore is the amount of water that is wasted while waiting for hot water to arrive at a fixture for the three types of systems. I stipulate that the amount of water actually used at each fixture for the intended use during the standard draw schedule is the same in all systems. This means that the differences in the energy use of the different systems is driven primarily by the relationship between the losses and in the case of the recirculation systems, by the additional cost of maintaining the temperature in the loop and in operating the pump.

The relative amount of water in a given length of pipe is dependent on the diameter of the pipe. This length is made up of a combination of trunk and branch for the standard systems and the branch only for the parallel piping systems. The parallel piping system will have less volume of water to displace than the standard system because the volume of water in the pipe will be less. However, the difference will only be due to the difference in the length of ¾ or 1″ diameter trunk. If a standard system has a short trunk and a long branch, then it approximates a parallel piping system. Conversely, if a standard system has a long trunk that passes close to the fixtures, it looks more like a recirculation system.

For recirculation systems, the loop is comparable to a very long manifold for a parallel piping system. No water is lost while getting the loop up to the desired temperature. The only water lost is in the 8-foot branches. It would appear that recirculation systems have the least wasted water of the three types. However, there are costs associated with operating the recirculation system, the least costly being the demand control type.

It seems to me that the following equation is the appropriate one to use for hot water distribution systems:

Distribution losses = Energy lost waiting for hot water to get to the fixture
+ Energy lost in the lines during use
+ Energy used to heat the water for a recirculation system
+ Energy used to run the pump for a recirculation system

The equation sums all of the distribution system losses. Point of Use water heaters would minimize all potential distribution losses, but they are unlikely to be cost effective to install. Unless they are all tankless or instantaneous, they will also suffer significant standby loss penalties when those are taken into account.

Systems with the least water loss and best insulation will come next. It seems very possible for well-designed and insulated demand control recirculation systems to be better than typical parallel piping systems. This will be due to the facts that they waste much less water, and because they are well insulated, they maintain high enough temperatures between draws so that the pump rarely comes on. Reductions in the first two losses more than make up for the costs of running the recirculation system. They are also much more likely than parallel piping systems to be able to provide the level of service described above.

A related issue is that we need to address the cases where distribution losses are greater than the energy used during the draw.

Some other minor points.

1. I like the fact that insulation is mandatory on the kitchen lines. Let's be sure that whether the line is a home run to the kitchen or the trunk serving the whole house, that the line is insulated.
2. The cost of pipe insulation appears high by more than 10%, so cost effectiveness would change. It might make insulating all lines mandatory. How sensitive is the conclusion regarding pipe insulation to the cost?
3. The timer and temperature control costs do not appear to include the cost of the pump, so cost effectiveness of these options would decrease. Please note that the aquastats typically sold for use in residential recirculation systems are set at the factory to operate in the range of 95-115F. They are not very accurate. This temperature range is insufficient to support the hot water temperatures shown in the standard schedule at least half of the time. The aquastats would need to be specified with a minimum setting of 105F. This can be done by the factory, but for an additional cost. However, this new lower setting means that the upper temperature will be 125F, which may very well be higher than future Federal and state regulations may allow.

4. Why shouldn't the clothes washer be within 8 feet of the recirculation loop or the water heater for that matter? Do we mean 8 feet of ½"diameter or less? Do we mean linear feet of pipe?
5. Before finalizing the regulations, it would be useful to verify the performance specifications with the manufacturers. For example, it is proposed to limit the pump capacity of the demand control systems to 1/12th horsepower. What happens if the pump manufacturer makes a slight change to their models and the correct model for the demand control manufacturer to use becomes 1/8th horsepower? I don't believe that it is our intent to limit their flexibility. What we are trying to do is to ensure that the most efficient and effective system is used for each application. Even with the larger horsepower pump, it runs so infrequently, the electricity costs will still be very small.

   Another question on the demand control systems is what is meant by push button(s)? One of the features that they offer is remote activation. This includes occupancy sensors, door switches, motion detectors and remote "push buttons". I assume that it is our intent to encourage many activation methods so that the consumer can choose the one(s) they prefer.

   Still another point is that while it is optimal to install the temperature sensor at the furthest fixture, this is not sensible on all plumbing designs. The 3080 sf house used in the analysis is a case in point. The way the plumbing was laid out with fixtures on both the outbound and return portions of the loop would lend itself to locating the sensor at the water heater. However, if the plumbing on the two wings was separated into two, the best location for the sensor would now be at the furthest fixture. This would reduce the energy costs assumed for the demand control system in several ways: 1)It would probably reduce the trunk to the kitchen from 1" to ¾". 2)It would eliminate a very long run between the kitchen and the guest bathroom with no fixtures on it; 3)It would mean that most of the use would be concentrated on one of the two systems, so that the line would remain charged for more uses; 4)No hot water would be in the return lines of either system; and 5)The pump size on the demand control system could be reduced, lowering the electrical costs of operation.

Thank you for this opportunity to assist the standards process. As mentioned in our discussions, I stand ready to work directly with your team to help resolve any outstanding issues and to craft language that will be used in the standards.